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CHAPTER 8

SAFETY

8.1 GENERAL

The purpose of this chapter is to provide guidance for evaluating and developing highway safety alternatives to be incorporated into roadway and structural designs. This includes providing for the safe accommodation of traffic through construction work zones. The safety guidelines of any highway facility are primarily a reflection of the attitude of the administration responsible for the facility and the priority placed on the use of available funds. While the overall objective is maximum highway safety, environmental and economical restraints may prohibit achieving this goal. The designer must, therefore, ensure that the design provides the maximum safety enhancements for each dollar spent.

Agreements have been negotiated with most of the Federal agencies with significant public road mileage, and they have active programs to meet the applicable guidelines. The FLH Divisions provide technical guidance to many of these agencies in the design and construction of their roads. In addition, they work to ensure that objectives of the *Highway Safety Guidelines* are accomplished.

8.1.1 Safety Design Policy

New construction and reconstruction involves the application of appropriate guidelines in the design and construction of the facility. (See [Chapter Nine](#).) The application of those guidelines virtually ensures uniform geometrics and safety. Even with their use, however, operational or roadside safety problems may still exist that will not be identified unless a safety analysis is performed.

It is Federal Lands Highway Office (FLHO) policy that RRR projects will be treated in a manner similar to new construction or reconstruction. Because of the limited scope of RRR projects, adoption of full guidelines may not be possible. When this occurs, the designer should identify the substandard features and analyze their potential effect on highway safety. The analysis and proposed mitigation are to be documented as discussed in [Section 9.1.2](#).

8.1.2 Roadway Safety

A crash is seldom the result of a single cause. Typically, several influences affect the situation at any given time. These influences can be separated into three elements:

- the human,
- the vehicle, and
- the environment.

The environmental element includes the roadway and its surroundings. The designer can only control roadway elements and must make a judicious selection of the roadway geometrics, drainage, surface type and other related items to lessen the potential for crashes and/or reduce the severity should they occur. The ideal design applies appropriate guidelines over a section of roadway.

The designer should avoid discontinuities in the highway environment. The following applies:

- abrupt changes in design speeds;
- short transitions in roadway cross section;
- short radius curves in a series of longer radius curves, or at the end of a long tangent;
- changes from full to partial access control;
- roadway width constrictions (e.g., narrow bridges, other structures);
- intersections and pullouts with inadequate sight distances;
- hidden sag vertical curves and inadequate sight distance at crest vertical curves; and/or
- other inconsistencies in the roadway design.

Standardizing highway design features and traffic control devices reduces driver confusion and makes the task of driving easier. Through the use of these standard features, the driver learns what conditions to expect on a certain type of highway. The goal, if possible, is to design a highway so that a driver needs to make only one decision at a time. Multiple decisions confuse and distract a driver.

8.1.3 Roadside Safety

Roadside safety design has become increasingly important as new technology has made possible improvements in the alignment, grade and roadway. When a vehicle leaves the roadway, any object in or near its path may become a contributing factor to the severity of the crash. The basic concept of a forgiving roadside is that of providing a clear recovery area where an errant vehicle can be redirected back to the roadway, stop safely or slow enough to mitigate the effects of the crash.

Consult the AASHTO *A Policy on Geometric Design of Highways and Streets (Green Book)* and the AASHTO *Roadside Design Guide* for guidance on appropriate clear recovery areas.

The designer must evaluate these requirements in conjunction with environmental and economic constraints to determine the acceptable clear zone for the traffic, speed and terrain of the project.

Potentially hazardous features located within the identified clear zone should be treated with one of the following options, which are listed in order of preference:

1. Remove the hazard.
2. Redesign the hazard so it can be traversed safely.
3. Relocate the hazard to a point where it is less likely to be struck, preferably outside the clear zone.

4. When a potential hazard remains in the clear zone, reduce the impact severity by using an appropriate breakaway device.
5. If the feature is potentially more hazardous than a barrier system that could shield it, consider installing a barrier system, a crash cushion or both.
6. If it is not feasible or practical to shield the hazard, delineate it.

8.2 GUIDANCE AND REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. While this list is not all-inclusive, the publications listed will provide a designer with additional information to supplement this *Manual*.

1. *Traffic Engineering Handbook*, Institute of Transportation Engineers, current ed.
2. *Local Highway Safety Studies Users Guide*, FHWA. Office of Highway Safety, July 1986.
3. [*Manual on Uniform Traffic Control Devices for Streets and Highways \(MUTCD\)*](#), FHWA, current ed. with approved revisions.
4. *Synthesis of Safety Research Related to Traffic Control and Roadway Elements*, Volumes I and II, FHWA, 1982.
5. *Traffic Control Devices Handbook*, ITE, current ed.
6. [*Roadway Delineation Practices Handbook*](#), FHWA, 1994.
7. *Identification of Hazardous Locations*, Report No. FHWA RD-77-87, FHWA, 1977.
8. *Highway Safety Engineering Studies - Procedure Guide*, Report No. FHWA-TS-81-220, FHWA, 1981.
9. *Traffic Control for Street and Highway Construction and Maintenance Operations Notebook*, FHWA, 1985.
10. *Alternate Approaches to Accident Costs Concepts*, FHWA, 1984.
11. *A Users Guide to Positive Guidance*, FHWA, September 1990.
12. [*Sign Manual*](#), US Department of the Interior, National Park Service, May 1988.
13. *Railroad-Highway Grade Crossing Handbook Users Guide*, Report No. FHWA-TS-86-216, FHWA, 2nd ed., September 1986.
14. [*Designing Safer Roads*](#), Special Report 214, Transportation Research Board, 1987.
15. [*Highway Capacity Manual*](#), Transportation Research Board, current ed.
16. [*Recommended Procedures for the Safety Performance Evaluation of Highway Features*](#), NCHRP Report No. 350, National Cooperative Highway Research Program, 1993.
17. *Safety Effectiveness of Highway Design Features*, Volumes I-VI, FHWA, 1992.
18. *Highway Safety Design and Operations Guide*, AASHTO, 1997.
19. *Roadside Safety Improvement Programs on Freeways — A Cost Effectiveness Approach*, Glennon, J.C., NCHRP 148, 1974.

20. *Roadside Design Guide*, AASHTO, current ed.

8.3 INVESTIGATION PROCESS

The investigation process begins with the initial consideration and priority given to candidate projects for safety improvements. FLH Program projects involve the preservation or improvement of the facility and the enhancement of roadway safety.

The majority of FLH projects involve existing roadways. On existing highways, historical information relating to the highway's operation or safety should be analyzed. State DOT's generally have operational and safety records for the Federal system. Respective agencies frequently have data for routes on their systems. Unfortunately, on off-system county roads, the available data may be scarce. This is often due to the low-volume rural nature of the facility. As a result, many crashes on these facilities go unreported. Information retrieval systems may also be less developed for these roads. Good sources of information are law enforcement officials, local maintenance personnel, property owners, local businesses, mail carriers, school bus companies, etc. A drive through of the project, with a keen eye towards operational or safety problems, or potential problems, will often detect areas requiring special attention during design.

8.3.1 Crash Data

Many State highway agencies maintain computerized crash files. They can provide statistics regarding statewide rates for fatal, injury and property damage crashes as well as rates on specific routes. By comparing statistical trends in a given area of the State, the designer may detect clues to the basic causes or problems that should be addressed during design. For example, if a proposed FLH Program project were located in a portion of a State that has a higher than normal run-off-the-road crash rate, further analysis of the types of crashes (e.g., skidding) may be warranted.

The designer should review available crash reports to determine if any engineering features may have contributed to the problem. Law enforcement agencies can usually provide available crash reports. In the case of the National Park Service (NPS), each park maintains its own crash reports. In the past, the NPS used the same crash report forms for all crashes, and no attempt was made, until recently, to separate and file vehicle crash forms together. Recognition of this problem, however, has resulted in a service-wide effort to standardize the data input as well as to computerize it for easy retrieval. This effort, initiated in 1985, is known as the Service-wide Traffic Crash Reporting System (STARS). STARS will provide substantial information to the designer.

8.3.2 Traffic Safety Studies

Traffic safety studies, when available, provide excellent references for evaluating safety and operational characteristics. The NPS has had traffic safety studies performed in many of their larger parks. The States or other agencies may also have such information available on their systems. While the content and form of traffic safety studies vary widely, they usually include an introduction that describes the goals and purpose of the study and defines the study area and project specifics.

8.4 SAFETY ANALYSIS AND DESIGN

The extent of appropriate safety enhancements on all projects can be determined by performing a safety analysis. A safety analysis consists of analyzing potentially hazardous features and locations; both the project's crash history and the list of potentially hazardous locations and features should be used during the project development process. At a minimum, the designer should review this information on each project where a design exception is requested. The project files should contain documentation of the safety analysis performed and any improvements or mitigations taken to enhance safety.

8.4.1 Crash Analysis

The amount of data available for analysis will vary from project-to-project as well as the level of detail and accuracy of the data. Therefore, the designer must determine on a case-by-case basis whether the data furnished for safety analysis purposes is satisfactory.

While not a typical function of the designer, lawsuits due to crashes may indicate the need to evaluate crash reconstruction. This involves drawing inferences concerning the interactions of speed, position on the road, driver reaction, comprehension and obedience to traffic control devices and evasive tactics. Crash reconstruction uses basic engineering knowledge of vehicle motion analysis, force analysis and mechanical energy.

8.4.1.1 Crash History

The crash history for the project should be developed and analyzed to determine possible causes and to select appropriate safety enhancements. Where practical, crashes should be summarized by location, type, severity, contributing circumstances, environmental conditions and time period. This will help identify high-accident locations (HAL) and may indicate some spot safety deficiencies.

Depending on how crash information is filed, it may be necessary to record the information first and then group all crashes occurring at specific locations. This serves to identify HALs. Analysis of the types of crashes can suggest appropriate corrective action. The use of computer spread sheet programs will enhance the ability to evaluate this data.

Special consideration should be given to analyzing crash data on RRR projects. Limited crash data are common on rural two-lane highways with low to moderate traffic volumes. The limited amount of this type of data often makes traditional methods of analysis difficult.

Data generated from a small sampling can be misleading because they can be significantly influenced by small variances. Analysis of many RRR projects may require the following special efforts:

- a study of individual crash reports including those just beyond the project termini,
- a review to relate crash data with field conditions, and

- interviews with maintenance and/or police personnel. These interviews may reveal areas where operational problems or minor crashes occur, but are not documented.

Crash analysis study procedures involve determining the significance of the crash history and developing summaries of the crash characteristics. The project's crash rates and summaries are used to detect abnormal crash trends or patterns and to distinguish between correctable and non-correctable crashes. Analyses of these summaries are used to identify possible safety deficiencies of the existing facility.

When summarizing crash data for analysis purposes, adhere to the following criteria:

1. **Time Period.** Select a time period for the collection of the crash data (e.g., five years). The time period chosen should contain reasonably current information on traffic volumes, pavement condition and other site-related data. Past changes in the character of the facility (e.g., physical changes, roadside development) are accounted for when evaluating the crash activity.
2. **Direction of Traffic.** Examine crash data with respect to the direction the vehicles were traveling.
3. **Location.** Examine crash data with respect to location. Crashes occurring within an intersection area should be separated from those occurring outside the area of influence of the intersection. In addition, similar crash types occurring in differing situations should be recorded separately. For example, left-turn crashes into a driveway should not be included with left-turn crashes at an intersection. Collision diagrams may be useful in the analysis.
4. **Project Termini.** Examine the number of crashes and the crash rates within the project termini. A comparison of this data with statewide norms for similar facilities should provide a reasonable indication of the relative safety of the existing roadway.
5. **Compare Crash Statistics.** Summarize the crash data and compare it to typical statistics on similar facilities. A specific crash type categorizes patterns. The identification of crash-type patterns may be used to suggest possible causes. Consider the severity patterns to determine if particular roadway or roadside features have contributed to the overall severity of the crashes that have occurred.
6. **Contributing Circumstances.** Summarize the contributing circumstances portion of the crash report. This identifies possible crash causes noted by the investigating police officer. Contributing circumstances are categorized by:
 - human (driver) factors,
 - vehicle related factors, and
 - environmental factors.

The contributing circumstances information is used to verify, add or delete possible causes developed by the crash summary by type procedure.

7. **Correctable Versus Non-Correctable Crashes.** The contributing circumstance data can be used to separate correctable and non-correctable crashes. In separating the

crashes by these classifications, careful consideration should be made to ensure that the crashes are indeed non-correctable. [Exhibit 8.4A](#) lists the contributing circumstances found on most crash reports and indicates if they are generally correctable or non-correctable through highway improvements.

8. **Environmental Conditions.** Summarize crashes by environmental conditions. This procedure identifies possible causes of safety deficiencies related to the existing condition of the roadway environment at the time of the crash. Typical classifications used in the analysis include lighting condition (i.e., daylight, dusk, dawn, dark) and roadway surface condition (i.e., dry, wet, snowy, icy, unknown).

These summaries are compared to average or expected values for similar locations or areas to determine whether the occurrence of a specific environmental characteristic is greater or less than the expected value at the location. For example, a higher than expected number of wet-surface crashes may be an indication of slippery pavement.

8.4.1.2 Probable Causes and Safety Enhancement

Probable crash causes need to be defined once the crash patterns are identified. On-site or photolog reviews of field conditions of crash sites are used to reduce the list of possible causes identified on the crash history to the most probable causes. The probable causes identified can then be used as a basis for selecting appropriate safety enhancements to alleviate the safety deficiency. [Exhibit 8.4B](#) is a listing of probable crash causes and possible safety enhancements. This list is not all-inclusive; however, it does provide a general list of possible crash causes as a function of crash patterns and appropriate safety enhancements.

8.4.2 Potentially Hazardous Locations and Features

Hazardous locations or features on existing roadways may or may not be HALs. Many locations with narrow bridges, slippery pavement, rigid roadside obstacles or other potentially hazardous conditions have crash potential but may not yet have a crash history. Therefore, it is important to identify potentially hazardous locations or features in the development of projects. When crash history is not available, a project listing of potentially hazardous features and locations may be used to determine the need for safety enhancements. Exhibit 8.4C presents an example of a roadside hazard review.

8.4.3 Alternative Evaluations

After the accumulation of available data, a roadside safety evaluation must be performed. The results of the crash analysis and the list of potential roadside hazards provide the input for this evaluation. From these two sources, the designer should develop a composite list that locates and describes the identified safety problems.

Alternatives for correcting the safety problems should be developed and each evaluated for effectiveness, cost and environmental impact. Alternatives may range from site-specific improvements to total reconstruction. The evaluations, alternatives and the action selected should be documented in the project files.

Driver-Related	
Unsafe speed (C/N)	Sick (N)
Failed to yield right-of way (C/N)	Fell asleep (C/N)
Following too close (C/N)	Lost consciousness (N)
Improper passing (C)	Driver inattention (C/N)
Disregard traffic controls	Distraction (C/N)
Turning improperly (C/N)	Physical disability (N)
Alcohol involvement (C/N)	Drug involvement (C/N)
Vehicle-Related	
Brakes defective (C/N)	Tow hitch defective (N)
Headlights defective (C/N)	Overload or improper loaded (N)
Other lighting defects (C/N)	Oversize load on vehicle (N)
Steering failure (N)	Tire failure/inadequate (C/N)
Environment-Related	
Animal on roadway (C/N)	Holes/deep ruts/bump (C)
Glare (C/N)	Road under construction/maintenance (N)
View obstructed/limited (C/N)	Improperly marked vehicle(s) (C/N)
Debris in roadway (N)	Fixed objects (C)
Improper/nonworking traffic controls (C/N)	Slippery surface (C)
Shoulders defective (C)	Water ponding (C)
Roadside hazards	

Key:

- (C) = Correctable
 (N) = Non-correctable by safety enhancement
 (C/N) = Either correctable or non-correctable depending on related circumstances

Exhibit 8.4-A CONTRIBUTING CIRCUMSTANCES

GENERAL CRASH PATTERN		
Crash Pattern	Probable Cause	Safety Enhancement
Run-off roadway	Slippery pavement	Improve skid resistance Provide adequate drainage Groove existing pavement
	Roadway design inadequate for traffic conditions	Widen lane/shoulders Relocate islands Provide proper superelevation Install/improve traffic barriers Improve alignment/grade Flatten slopes/ditches Provide escape ramp
	Poor delineation	Improve/install pavement markings Install roadside delineators Install advance warning signs
	Poor visibility	Improve roadway lighting Increase sign size
	Inadequate shoulder	Upgrade roadway shoulder
	Improve channelization	Improve channelization
Bridges	Alignment	Realign bridge/roadway Install advance warning signs Improve delineation/markings
	Narrow roadway	Widen structure Improve delineation/markings Install signing/signals
	Visibility	Remove obstruction Install advance warning signs Improve delineation and markings
	Vertical clearance	Rebuild structure/adjust roadway grade Install advance warning signs Improve delineation and markings Provide height restriction/warning
	Slippery surface (wet/icy)	Resurface deck Improve skid resistance Provide adequate drainage Provide special signing
	Rough surface	Resurface deck Rehabilitate joints Regrade approaches

Exhibit 8.4-B GENERAL CRASH PATTERNS

GENERAL CRASH PATTERN		
Crash Pattern	Probable Cause	Safety Enhancement
	Inadequate barrier system	Upgrade bridge rail Upgrade approach rail/terminals Upgrade bridge - approach rail connections Remove hazardous curb Improve delineation and markings
Overturn	Roadside features	Flatten slopes and ditches Relocate drainage facilities Extend culverts Provide traversable culvert end treatments Install/improve traffic barriers
	Inadequate shoulder	Widen lane/shoulder Upgrade shoulder surface Remove curbing/obstructions
	Pavement feature	Eliminate edge drop-off Improve superelevation/crown
Parked vehicles	Inadequate road design	Widen lane/shoulders
Fixed object	Obstructions in or too close to roadway	Remove/relocate obstacles Make drainage headwalls flush with side slope Install breakaway features to light poles, signposts, etc. Protect objects with guardrail Delineation/reflectorize safety hardware
	Inadequate lighting	Improve roadway lighting
	Inadequate pavement markings, signs, delineators, and guardrail	Install reflectorized pavement lines/raised markers Install reflectorized paint and/or reflectors on the obstruction Add special signing Upgrade barrier system
	Inadequate road design	Improve alignment/grade Provide proper superelevation Install warning signs/delineators Provide wider lanes
Sideswipe or head-on	Slippery surface	Improve skid resistance Provide adequate drainage Groove existing pavement
	Inadequate road design	Provide wider lanes Improve alignment/grade Provide passing lanes Provide roadside delineators Sign and mark unsafe passing areas
	Inadequate shoulders	Improve shoulders

Exhibit 8.4-B GENERAL CRASH PATTERNS
(Continued)

GENERAL CRASH PATTERN		
Crash Pattern	Probable Cause	Safety Enhancement
	Excessive vehicle speed Inadequate pavement markings Inadequate channelization Inadequate signing	Install median devices Install/improve centerline, lane lines and edge lines Install reflectorized markers Install acceleration and deceleration lanes Improve/install channelization Provide turning bays Provide advance direction and warning signs Add illuminated name signs
Access-related	Left-turning vehicles Improperly located driveway Right-turning vehicles Large volume of through traffic Large volume of driveway traffic Restricted sight Inadequate lighting	Install median devices Install-two-way left-turn lanes Move driveway to side street Install curbing to define driveway locations Consolidate adjacent driveways Provide right-turn lanes Increase width of driveways Widen through lanes Increase curb radii Move driveway to side street Construct a local service road Signalize driveway Provide acceleration and deceleration lanes Channelize driveway Remove obstructions Improve street lighting
Intersection (signalized/ unsignalized) left turn, head-on, right angle, rear end	Large volume of left/right turns Restricted sight distance	Widen road Channelize intersection Install STOP signs Provide signal Increase curb radii Remove sight obstruction Provide adequate channelization Provide left/right-turn lanes Install warning signs Install STOP signs Install signal Install advance markings to supplement signs Install STOP bars

Exhibit 8.4-B GENERAL CRASH PATTERNS
(Continued)

GENERAL CRASH PATTERN		
Crash Pattern	Probable Cause	Safety Enhancement
	Slippery surface	Improve skid resistance Provide adequate drainage Groove pavement
	Large numbers of turning vehicles	Provide left- or right-turn lanes Increase curb radii Install signal
	Inadequate lighting	Improve roadway lighting
	Lack of adequate gaps	Provide signal Provide STOP signs
	Crossing pedestrians	Install/improve signing or marking of pedestrians crosswalks Install signal
	Large total intersection volume	Install signal Add traffic lane
	Excessive speed on approaches	Install rumble strips
	Inadequate traffic control devices	Upgrade traffic control devices
	Poor visibility of signals	Install/improve advance warning signs Install overhead signals Install 300 mm (12 in) signal lenses Install visors/back plates Relocate signals Remove sight obstructions Add illumination/reflectorized name signs
	Unwarranted signals	Remove signals
	Inadequate signal timing	Upgrade signal system timing/phasing
Nighttime	Poor visibility or lighting	Install/improve street lighting Install/improve delineation/markings Install/improve warning signs
	Poor sign quality	Upgrade signing Provide illuminated/reflectorized signs
	Inadequate channelization or delineation	Install pavement markings Improve channelization/delineation

Exhibit 8.4-B GENERAL CRASH PATTERNS
(Continued)

GENERAL CRASH PATTERN		
Crash Pattern	Probable Cause	Safety Enhancement
Wet pavement	Slipper pavement	Improve skid resistance Groove existing pavement
	Inadequate drainage	Provide adequate drainage
	Inadequate pavement markings	Install raised/reflectorized pavement markings
Pedestrian/bicycle	Limited sight distance	Remove sight obstructions Install/improve pedestrian crossing signs and markings
	Inadequate protection	Add pedestrian refuge islands
	Inadequate signals/signs	Install/upgrade signals/signs
	Mid-block crossings	Install warning signs/markings
	Inadequate pavement markings	Supplement markings with signing Upgrade pavement markings
	Lack of crossing opportunity	Install traffic/pedestrian signals Install pedestrian crosswalk and signs
	Inadequate lighting	Improve lighting
	Excessive vehicle speed	Install proper warning signs
	Pedestrians/bicycles on roadway	Install sidewalks Install bike lanes/path Eliminate roadside obstructions Install curb ramps
	Long distance to nearest crosswalk	Install pedestrian crosswalk Install pedestrian actuated signals
Railroad crossings	Restricted sight distance	Remove sight obstructions Reduce grade' Install active warning devices Install advance warning signs
	Poor visibility	Improve roadway lighting Increase size of signs Install advance markings to supplement signs
	Inadequate pavement markings	Install STOP bars Install/improve pavement markings
	Rough crossing surface	Improve crossing surface
	Sharp crossing angle	Rebuild crossing with proper angle

Exhibit 8.4-B GENERAL CRASH PATTERNS
(Continued)

State: Montana
 County: Flathead

Prepared by: Paul Schneider
 Date: May 19, 1996

National Forest/Park: Glacier National Park

Highway Route: U.S. Route 2 Limits: 193+116 to 202+128 Length: 9.0 km

General Location: Beginning 1 km south of Camas and extending north to top of graveyard hill at Essex.

Item	Hazard Location		Description of Hazard	Action	Cost	Remarks
	Station	Lt/Rt (m)				
1	193+438	6.0 Rt	100 x 100 wood sign post	Yes	\$ 90	Relocate to backslope
2	194+082	4.9 Rt	100 x 100 wood sign post	Yes	\$ 90	Relocate to backslope
3	194+243	5.5 Lt	Concrete culvert headwall	Yes	\$ 500	Replace existing culvert
4	194+323	4.9 Rt	Concrete culvert headwall	Yes	\$ 600	Replace existing culvert
5	194+564	3.7 Lt	Mailbox in no-passing zone	Widen	\$1000	Provide mailbox turnout
6	194+886	4.3 Rt	Two 100 x 150 wood sign posts (not drilled)	Yes	\$ 50	Drill posts
7	195+530	4.9 Lt	Abrupt culvert ends	Yes	\$ 250	Lengthen culvert - metal end sections
8	196+013	4.6 Lt	Mailbox - good sight distance	No	-	Tight right-of-way
9	196+013	5.5 Lt	Abrupt approach road culvert	Yes	\$ 600	Extend approach culvert and flatten slope to 1:10
10	196+174 to 196+656	6.7 Rt	Steep fill slope	None	-	Not cost effective guardrail
11	197+300	6.0 Lt	Concrete culvert headwall	Yes	\$ 500	Replace and extend
12	198+105	5.5 Rt	Abrupt approach road culvert	Yes	\$ 600	Extend culvert and flatten slope to 1:10
13	200+680	4.3 Rt	Concrete culvert headwall	Yes	\$ 500	Replace existing culvert
14	201+645	3.7 Lt	Mailboxes (4)	Widen	\$2500	Provide mailbox turnout

Exhibit 8.4-C SAMPLE ROADSIDE HAZARD REVIEW

8.4.4 Clear Zone

A clear zone (L_c) is defined as the roadside border areas (starting at the edge of the traveled way) that is available for safe use by errant vehicles. The width of the clear zone is influenced by the type and volume of traffic, speed, horizontal alignment and side slopes. Slopes steeper than 1V:4H are considered non-recoverable and slopes steeper than 1V:3H are not considered traversable by vehicles. The need for traffic barriers as discussed in Section 8.4.5 should be evaluated when slopes within the clear zone are in these ranges. The *AASHTO Roadside Design Guide* also discusses clear zone widths.

Determine clear zone widths for all roadway sections by using Table 3.1 or Figure 3.1 of the *AASHTO Roadside Design Guide*. Where feasible and environmentally acceptable, the clear zone width should be a minimum of 3 m (10 ft). On rural collectors and local roads and streets with a design speed of less than 60 km/h (40 mph) or an ADT less than 750, the clear zone width may be determined and documented on a project-by-project basis.

8.4.5 Traffic Barriers

When clear zone requirements cannot be met, the designer should give special attention to the roadside hazards. Obstacles located within the clear zone should be removed, redesigned, relocated or made breakaway. If this is not feasible, then guardrail or some other type of roadside barrier should be considered, provided that the roadside barrier offers the least hazard potential. If it is determined that a traffic barrier is not needed, consider delineating the hazard.

8.4.5.1 Determining Needs

Roadside obstacles may be classified as non-traversable hazards or fixed objects.

The following are examples of non-traversable hazards that may warrant roadside barriers:

- steep embankments (slopes steeper than 1V:3H),
- rock cuts,
- large boulders,
- ditches,
- culvert openings,
- permanent bodies of water over 0.6 m (2.0 ft) in depth,
- large trees over 100 mm (4 in) diameter, and/or
- shoulder edge drop-offs steeper than 1V:1H and depth greater than 0.6 m (2.0 ft).

A ditch section is safe or hazardous depending upon the type of sideslopes and widths. The *Roadside Design Guide* contains examples for a variety of ditch configurations. Frequently, limited right-of-way, environmental factors and terrain will preclude the designer from being able to develop these preferred ditch sections. Preferred ditch sections should receive greater consideration on high-speed, high-volume facilities. Medians on divided roadways also deserve special attention.

The following are examples of fixed objects that may warrant roadside barriers:

- bridge piers, abutments, parapets, or railings;
- retaining walls;
- the fixed sign bridge and non-breakaway sign supports;
- trees over 100 mm (4 in) in diameter;
- headwalls of box culverts or pipe culverts;
- culvert end sections with diameters larger than 900 mm (36 in); and/or
- utility appurtenances.

The unprotected end of a bridge rail or parapet is considered a hazard. In most designs, an approach roadside barrier with a smooth transition to the bridge barrier is warranted. Exceptions to this policy may include structures designed for use on low-volume, low-speed highways. The *Roadside Design Guide* contains discussions for transition barriers.

Special attention should be given to the proper attachment of the transition railing with the bridge railing or parapet. The railing connection should develop the full tensile strength of the rail element and be designed to prevent possible pocketing or snagging of a vehicle on the end of the bridge parapet. The bridge plans should generally include special drawings of these connection details. Transition guardrail should satisfy the minimum length of need to develop its full tensile strength capacity. The terminal end should extend outside the lateral clear zone or be provided with a crash worthy terminal, protected by a crash cushion or buried in a cut slope.

On many projects, existing bridges have inadequate bridge or transition railings. When replacing structurally obsolete bridges, railing replacement should meet current standards. When bridge railings are structurally adequate but functionally obsolete, engineering analysis should be performed to determine the recommended action on a case-by-case basis.

Crashes involving roadside hazards represent a problem inherent to any existing highway facility. Even on new or reconstructed projects, the complete elimination of all roadside hazards may not be feasible or practical. See [Section 8.1.3](#) for a priority list when evaluating roadside hazards.

Appendix A of the *Roadside Design Guide* provides a cost-effective selection procedure for comparing alternative solutions to problem locations and instructions for operating the Roadside Safety Analysis Program (RSAP) computer software. The annual cost of each alternative is computed over a given period of time, taking into consideration initial costs, maintenance costs and crash costs. Crash costs incurred by the motorist, including vehicle damage and personal injury, are considered together with crash costs incurred by the highway department or agency. The alternative with the least total cost is normally selected, except when environmental or aesthetic considerations dictate otherwise.

When determining the need for traffic barriers, consider cost when evaluating the following four alternatives:

1. **Remove or Reduce Hazard.** This option should only be considered if it is determined that shielding is unnecessary.
2. **Install a Barrier.** With regard to installing a barrier, RSAP allows the designer to evaluate any number of barriers that can be used to shield the hazard. Through this method the following can be evaluated:

- the effects of average daily traffic,
- offset of barrier or hazard,
- size of barrier or hazard, and
- the relative severity of the barrier or the hazard.

The ability to easily vary input data allows the designer to explore various areas of sensitivity of the analysis at a given location. The effects of current traffic and future traffic can be explored to evaluate cost effectiveness over the design life of a project. Although most of the data collected through research pertains to high-speed situations, the designer can analyze how sensitive the cost effectiveness is with respect to the severity index. However, a correlation can be made provided the designer recognizes that lower design/running speeds would lessen severity. Use of this tool has been successful in persuading reluctant agencies to recognize the cost effectiveness of selected safety feature applications.

This program accesses research information by Kennedy-Hutcheson for high-volume roads and Glennon for low-volume roads with roadway widths less than 8.5 m (28.0 ft). The program shows both annual cost comparison and present worth. Generally, the annual cost is used to facilitate comparison of different alternatives with varying design life.

For low-volume, low-speed roads, strict adherence to the guardrail warrants shown in the *Roadside Design Guide* is frequently not practical nor cost-effective. NPS and FHWA have jointly developed [Park Road Standards](#), published by NPS in 1984. Although developed specifically for NPS roads, the basic principles in these *Standards* are applicable to other types of low-volume, low-speed roads.

The *Park Road Standards* states:

Guardrail or guardwalls should be installed at points of unusual danger such as sharp curves and steep embankments, particularly at those points that are unusual compared with the overall characteristics of the road.

Similar wording is used in the AASHTO *Green Book* in the section that deals with recreational roads.

Although the *Guides* are still used as a basis for determining need for barriers on recreational roads, they are not always applicable to these roads. Besides low speeds and low volumes, NPS roads frequently have other characteristics that affect barrier needs. These include the following:

- roads closed in winter and during periods of hazardous climatic conditions,
- roads closed at dark, and
- roads with access limited to passenger-carrying vehicles.

Another consideration affecting the use of barriers is for areas that have unusual environmental sensitivity (e.g., endangered plants and animals, major historic and scenic resources).

The “unusual danger” noted in the NPS standard, when compared with the rest of the roadway, has been reduced to the following criteria for roads that have continuous sharp curves and steep slopes throughout much of their lengths:

- a. Consider barriers in areas with high embankments and slopes steeper than 1V:2H and where rock embankments and retaining walls prevent the growth of vegetation.
- b. Consider barriers in areas with steep slopes or other roadside hazards where unusual conditions exist that may surprise or distract the motorist. For example, sharp curves at the end of long tangents (especially on downgrades) or approaches to scenic vistas at sharp curves.
- c. Consider barriers at locations with crash histories where the severity could have been reduced with a barrier.

Always remember that a barrier is itself a significant hazard and is more likely to be hit than the hazard it is intended to protect. Therefore, the relative severity, costs and frequency of crashes must be considered.

Although the warrants cover a wide range of roadside conditions, special cases or conditions will arise for which there is no clear choice. Such cases must be evaluated on an individual basis, and, in the final analysis, must usually be solved by engineering judgment.

3. **Sight or Delineate Hazard.** Signing or delineating a hazard is typically cost-effective on low-volume and/or low-speed facilities, or where the probability of crashes is low.
4. **Do Nothing.** Option 4 determines that other alternatives are not cost-effective in reducing the risk of crashes.

8.4.5.2 Type Selection

Once it has been determined that a barrier is needed, type selection will be made. While the most predominant type of roadside barrier used on Federal Lands' projects is metal W-beam guardrail, the designer needs to be cognizant of various selection criteria for roadside barriers. [Exhibit 8.4D](#) lists the various criteria that should be considered.

The designer is again referred to the *Roadside Design Guide* and the approved hardware website (<http://safety.fhwa.dot.gov/report350hardware>) for design criteria of the various systems.

Crash tests performed for FLHO using the [National Cooperative Highway Research Reports \(NCHRP\) 230 and 350](#) criteria to evaluate aesthetic barrier systems indicated acceptable crash test results. For design and construction notes on these systems, see http://www.efl.fhwa.dot.gov/techdev/abs_index.htm. Research efforts are in progress to identify and crash-test other systems for possible use on FLH Program projects.

Characteristic	Considerations
Deflection	Space available behind barrier must be adequate to permit dynamic deflection of barriers.
Strength and Safety	System should contain and redirect vehicle at design conditions. System should be as safe as possible considering costs and other considerations.
Maintenance	Collision maintenance. Routine maintenance. Environmental conditions. Inventory of spare parts.
Compatibility	Can system be transitioned to other barriers? Can system be terminated properly?
Costs	Initial costs. Maintenance costs. Accident cost to motorist.
Field experience	Documented evidence of barrier's performance in the field.
Aesthetics	Barrier should have a pleasing appearance.
Promising new designs	It may be desirable to install new systems on an experimental basis.

Exhibit 8.4-D SELECTION CRITERIA FOR ROADSIDE BARRIERS

The owner agency generally selects the type of roadside barrier. It is the designer's responsibility to ensure that the selected barrier has been tested and approved for use and designed to function where installed.

The FHWA Final Rule, published in the *Federal Register* on July 16, 1993, required that roadside safety hardware installed on the National Highway System (NHS) routes must meet the requirements of [NCHRP 350](#). The FLH policy requiring barriers systems to meet the requirements of NCHRP 350 is provided below:

1. **Routes on the NHS.** The following applies:
 - a. **State and local routes:** As required by FHWA, it is the policy of the FLH to use only roadside safety hardware that meets NCHRP 350 criteria. Except for specific hardware items receiving delays or temporary waivers granted by the FHWA, Office of Safety Design (HSA-10), no exceptions are permitted.

- b. **National Park Service (NPS) routes:** It is also the policy of the FLH that all roadside safety hardware shall meet [NCHRP 350](#) criteria on NPS routes.

A request for acceptance of aesthetic barrier systems previously accepted under NCHRP 230 may be submitted to the Office of Safety Design for consideration. The Office of Safety Design may determine that the barrier is acceptable under NCHRP 350 criteria without retesting, if the test result data under [NCHRP 230](#), or results from similar systems tested under NCHRP 350, indicate the system is likely to meet NCHRP 350 criteria.

- 2. **Routes not on the NHS.** The FLH shall comply with the owning agency's policies on roadside safety hardware on non-NHS routes. The owning agency's policies will be referenced as the reasons for permitting barrier systems that do not meet NCHRP 350 criteria. However, no barrier systems shall be used that have not passed NCHRP 230 criteria. If the agency has no policy, FLH shall specify roadside safety hardware that meets NCHRP 350 criteria. Although there is no regulatory requirement, the FHWA strongly encourages safety hardware used on non-NHS routes to meet NCHRP 350 criteria.

- a. **State and local routes:** Due to particular issues (e.g., maintenance of barrier systems) State or local agencies may require barrier systems that do not meet NCHRP 350 criteria. The FLH Divisions shall ensure the owning agencies are aware that proposed systems do not meet NCHRP 350 criteria before complying with the owning agencies' requests. The FLH Divisions should document reasons for specifying barrier systems that do not meet NCHRP 350 criteria.
- b. **NPS routes:** All barrier systems shall meet NCHRP 350 criteria. The decision to use barrier systems that do not meet NCHRP 350 criteria should be documented.

Roadside safety hardware meeting NCHRP 350 criteria are currently being accepted by the Office of Safety Design following a review of data submitted by the vendor or the developer of the system. Updated lists of approved barrier systems may be found on the FHWA website, <http://safety.fhwa.dot.gov/report350hardware>. If no acceptable non-proprietary barrier terminal systems and transitions are available that meet the project needs, at least three acceptable proprietary systems (if available) shall be permitted as options in the contract.

8.4.5.3 Design Procedures

Once the need for barrier has been determined, the designer must determine the length and location for the barrier. The following discussion outlines the significant elements for locating and designing roadside barriers. However, the designer must refer to the *Roadside Design Guide* for specific details and limiting criteria for layout and use of the barrier selected.

8.4.5.3.1 Length of Barrier

The length of need is equal to the length of the area of concern parallel to the roadway, plus the length of the approach barrier on the upstream side (and downstream side, if needed), plus a safety end treatment.

Where slopes outside of the graded shoulder are flat enough, the barrier approach should be flared or the guardrail installation should be located outside of the graded shoulder to minimize the length of need. More commonly, where slopes are steeper, the barrier will run along the shoulder. Exhibit 8.4E depicts both cases. The minimum barrier lengths in advance of the hazardous area shown are adequate for most installations.

8.4.5.3.2 Location of Barrier

1. **Adjacent to the Graded Shoulder.** Designers should be aware that barrier installations require widening of the shoulder to provide adequate soil support. In addition, special attention is required at barrier terminals to ensure that widened areas are graded correctly so that the terminal will function properly.
2. **Back of the Graded Shoulder.** Where barriers are located in back of the graded shoulder or when barriers are flared back of the shoulder edge, slopes in front of the barrier shall be 1V:10H or flatter. Also, the algebraic difference between the shoulder slope and the slope in front of the guardrail should not be greater than 8 percent.

8.4.5.3.3 Barrier/Curb Combinations

1. **All Barrier/Curb Combinations.** Concrete curb and gutter, header curb or other rigid-type curb used in combination with a barrier should be avoided whenever possible. Curbs should not be used in front of barriers unless the combination has been successfully crash-tested.
2. **Guardrail/Curb Combinations.** Where there are no other feasible alternatives to guardrail/curb combinations, the face of curb should be located behind or flush with the face of guardrail. However, crash tests have shown some guardrail/curb combinations with curbs located flush with the face of the guardrail can cause vaulting due to deflection of the rail. Therefore, curbs higher than 100 mm (4 in) should not be used with guardrail unless:
 - the guardrail/curb combination has been successfully crash-tested; or
 - the rail is adequately reinforced (stiffened) to reduce its deflection.

On lower speed roads, use of a reinforced rail may not be cost-effective. These locations are best analyzed on a case-by-case basis, taking actual or anticipated operating speeds into account and considering the consequences of vehicular penetration.

The *Roadside Design Guide* contains additional information on curb and barrier/curb combinations.

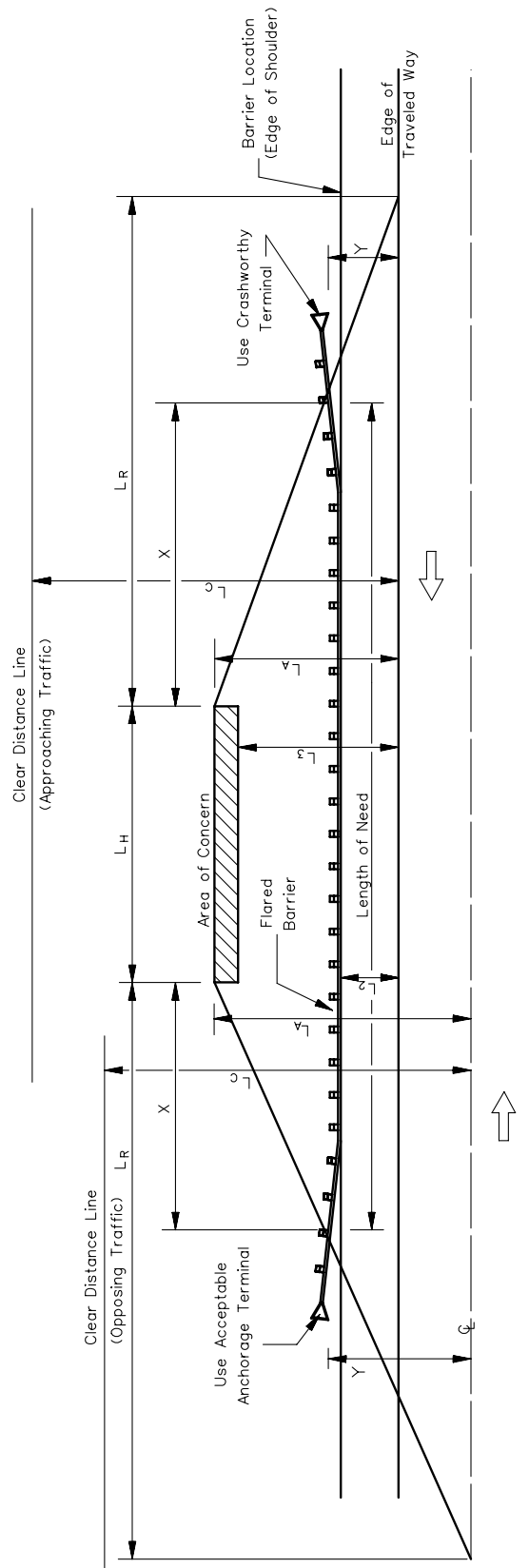


Exhibit 8.4-E GUARDRAIL LENGTHS REQUIREMENTS

Note: This Exhibit also applies to roadside hazards on two-way roadways where shielding is required for the opposing flow of traffic.

L_2 = Distance to barrier
 L_C = Clear zone
 L_A = Distance to back of hazard
 L_3 = Distance to front of hazard
 L_R = Runout length
 X = Length needed for approach end
 L_H = Length of hazard

8.4.6 Crash Cushions

Crash cushions shield errant vehicles from impacting fixed rigid hazards (e.g., an intersection of bridge parapets at a gore area) by smoothly decelerating the vehicle to a stop condition when hit head on. Also, it is desirable for the crash cushion to redirect a vehicle when hit from the side by functioning in a manner similar to a longitudinal barrier.

8.4.6.1 Determination of Need

As with longitudinal barriers, the first consideration with regard to a rigid object or a hazardous condition is to evaluate the feasibility of removing the obstruction, relocating it or making it breakaway. When these options are not feasible, the next step is to determine whether or not analyzing the cost effectiveness warrants some type of barrier described in [Section 8.4.5](#). The cost-effective procedure can be used to evaluate both longitudinal barriers as well as crash cushions. Before the development of crash cushions, many fixed object hazards could not be effectively shielded at all; therefore, where appropriate, crash cushions may prove to be very helpful.

8.4.6.2 Types of Crash Cushions

The *Roadside Design Guide* presents several approved crash cushions. Updated lists of approved crash cushions may be found on the FHWA website, <http://safety.fhwa.dot.gov/report350hardware>. Crash test criteria can be found in [NCHRP Report 350](#).

8.4.6.3 Design Procedures

While the use of crash cushions on FLH projects is expected to be quite limited, the designer should realize that rapid development in this area is occurring. Where use of a crash cushion is warranted, the designer should ensure that the most recent design criteria are used.

8.4.7 Signing and Delineation

Communication with the motorist is one of the most complex problems of the design engineer. One of the best communication tools available is the [MUTCD](#), which depicts the national standards developed for all signing, signalization, channelization and pavement markings for all highways in the United States. FHWA *Standard Highway Sign Book* and the [NPS Sign Manual](#) both provide design criteria, methods and charts for design.

All traffic control devices shall be in accordance with the *MUTCD*. Compliance with the requirements of the *MUTCD* for all traffic control devices is mandatory and includes the following:

- use;
- placement;
- uniformity;
- maintenance;

- color;
- size;
- shape;
- legend;
- retro-reflectivity; and
- removal, when not applicable.

The main message of the [MUTCD](#) is the importance of uniformity. Substantial adherence to this *Manual* is required on all public roads. However, some owner agencies have supplements or have developed similar manuals (e.g., the [NPS Sign Manual](#)), that must also be considered when designing and constructing roads under NPS jurisdiction. The *Traffic Control Devices Handbook* provides a compendium of traffic control system technology.

Highway users are dependent on traffic-control devices (i.e., signs, markings, signals) for information, warning and guidance. Uniform high-quality devices are important for the safe, efficient use and public acceptance of any highway regardless of the roadways excellence in width, alignment and structural design.

Any traffic control device should meet all the following requirements:

- fulfill an important need;
- command attention;
- convey a clear, simple meaning;
- command respect of road users; and
- give adequate time for proper response.

It should be noted that law must sanction devices controlling or regulating traffic.

The following aspects should be carefully considered in order to maximize the ability of the traffic control device to meet the five requirements listed above:

- design,
- placement and operation,
- maintenance, and
- uniformity.

Consideration should be given to these principles during the design stage to ensure that the required number of devices can be minimized and properly placed.

8.4.7.1 Signing

The above-cited references provide the designer with the information required to properly select the appropriate signing. Sign supports should be designed in accordance with the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*. Owner agency practice, in accordance with the above standards, may dictate the types of materials to be used. Sign supports and luminaries located within the clear zone shall meet the requirements of [NCHRP 350](#).

Designers should be aware that the [NPS-52 Traffic Control Guideline](#) requires each park to have an established sign plan. These plans should be reviewed together with crash statistics and any available safety studies to ensure continued appropriateness whenever additional construction work takes place. Similar plans may exist on specific routes with other owner agencies and should likewise be requested and reviewed.

The authority for regulatory signing rests with the maintaining/regulating agency. Likewise, the client agency may have specific concerns regarding warning or informational signs. The designer's responsibility is to identify all signs required and review them with the appropriate agencies during project development.

8.4.7.2 Pavement Markings

Pavement markings have definite and important functions to perform in a proper scheme of traffic control. In some cases, they are used to supplement the regulations or warnings of other devices (e.g., traffic signs, signals). In other instances, they are used alone and produce results that cannot be obtained by the use of any other device. In these cases, they serve as a very effective means of conveying certain regulations and warnings that could not otherwise be made clearly understandable.

Pavement markings have definite limitations. They can be obliterated by snow, may not be clearly visible when wet and may not be very durable when subjected to heavy traffic. In spite of these limitations, they have the advantage, under favorable conditions, of conveying warnings or information to the driver without diverting the driver's attention from the roadway.

8.4.7.2.1 General Application

Each standard marking shall be used only to convey the meaning prescribed for it in the [MUTCD](#). Before any new paved highway, surfaced detour or temporary route is opened to traffic; all necessary markings must be in place.

Remove or obliterate markings no longer applicable, or which may create confusion in the mind of the motorist, as soon as practicable. Painting over markings is not an acceptable method of obliteration. Markings must be retro-reflective.

All markings must be placed in accordance with the *MUTCD*.

8.4.7.2.2 Pavement Marking Materials

The standard material to be used for pavement markings is an applied paint with reflective beads. All other pavement-marking materials are considered to be upgraded materials. To upgrade, consideration must be given to material performance, material cost, traffic volume and type, climatic conditions, availability of materials and installation equipment (both for initial installation and maintenance). Only when an upgraded material is established to be more cost-effective than the standard material, can the upgraded material be used. The following guidelines may be used for upgrading the striping material in lieu of an economic evaluation:

1. Epoxy thermoplastic (ETP), epoxy, and polyester materials may be specified for centerlines, lane lines and edge lines under any of following conditions:
 - a. the ADT is in excess of 1,000 vehicles per lane;
 - b. because of environmental, traffic or climatic conditions, it is necessary to restripe with paint two or more times a year; or
 - c. the location is not proposed or scheduled for sealing or resurfacing within the next three years.
2. Additionally, thermoplastic and preformed plastic type materials may be allowed for centerlines, lane lines and edge lines when both of the following conditions are met:
 - a. the ADT is in excess of 5,000 vehicles per lane, and
 - b. the location is not proposed or scheduled for sealing or resurfacing within the next five years.

Epoxy thermoplastic, epoxy or polyester materials may be specified under lower traffic conditions where there is a need to emphasis transitions, channelization or special markings (e.g., stop lines and crosswalks). These materials should not be specified under the lower traffic condition if it is less than three years before the pavement is scheduled for sealing or resurfacing.

3. The appropriate type of raised pavement markings and/or snow plowable recessed low profile markers should be considered for the following:
 - a. intersection channelization,
 - b. directional left-turn lanes,
 - c. high hazard/crash locations,
 - d. areas of frequent inclement weather,
 - e. combined installations with preformed plastic markings where no overhead lighting exists, and
 - f. gore areas and approaches to deceleration lanes.

Pavement striping tape may be specified as a temporary measure when conditions do not permit painting or while the highway is under construction.

8.4.8 Traffic Control

The safe and efficient movement of traffic through the highway project necessitates that designers review the proposed design from a traffic operations standpoint. The designer needs to be alert for situations that involve alterations in the driver's behavior or changes in driver attention. During the design phase, attempt to perceive the final roadway as it will appear to the

motorist to anticipate the necessary traffic control devices needed to provide the user with sufficient advance information so the highway can be driven safely. Through the proper application of design standards, the number of motorist decision points will be minimized. There will, however, always be a need for appropriate permanent traffic control devices to inform, regulate and/or warn the motorist. A review of the safety analysis will generally identify areas of existing operational problems.

Field reviews during construction are encouraged to substantiate if the original perceived operational characteristics of the project were germane and to provide timely adjustments during construction should they be warranted. After construction is completed and the project opened to traffic, an evaluation should be made of the traffic control devices to determine their adequacy and if they are functioning as planned.

8.4.8.1 Traffic Control Through Construction

Construction activity presents many traffic control problems that must be addressed by the designer. Regardless of whether the project is open or closed to public traffic, some form of construction traffic control will be required. A plan directed to the safe and expeditious movement of traffic through construction and to the safety of the work force performing those operations is defined as a Temporary Traffic Control (TTC) Plan.

It is FLHO policy that a TTC plan be designed and incorporated into all projects.

8.4.8.2 Temporary Traffic Control (TTC) Plan Development

The purpose of the TTC plan is to anticipate and describe those traffic control measures that will be necessary during project construction and to outline coordination needs with owner agencies and the public.

TTC plans will vary in scope and complexity depending upon the type and volume of traffic and the nature of the construction project. At an early stage in the project development, the development of the TTC plan should begin and a determination made of the nature and volume of current and predicted traffic. All interested agencies should be involved throughout the development of the TTC plan. For projects with low-traffic volumes or that otherwise have few traffic hazards or conflicts, the TTC plan may be quite simple.

For projects that have one or more of the following characteristics, the TTC plan will normally be more complex:

- high-volume or high-speed traffic;
- rush hour or seasonal traffic patterns;
- heavy use by bicycles, pedestrians or disabled persons;
- changing work conditions or other conditions that would be confusing to the traveling public;

- hazards due to nighttime operations;
- detours or complex traffic patterns; and/or
- closely spaced intersections, interchanges or other decision points.

In developing the TTC plan, consider the items in [Exhibit 8.4F](#) as appropriate. These items may be used as a checklist in either developing or reviewing the adequacy of traffic control plans.

All TTC plan features, which are obligations on the part of the contractor, shall be included in the plans and specifications. When necessary, appropriate project-specific or standard typical traffic schemes shall be included in the plans.

The [MUTCD](#) must be used as a standard for signs, striping and other traffic control devices. Because of the general nature of the *MUTCD*, it will usually be necessary to use supplemental information.

The contract PS&E must include the minimum requirements for controlling traffic through the construction work zones. However, the contractor may furnish alternate or additional means for accommodating traffic, subject to approval of the engineer.

Include traffic control provisions in the PS&E distribution made to other offices and agencies for review before advertising in order that these other parties may have an opportunity to review the provisions for adequacy and coordination.

Payment for TTC plan activities will usually be made by individual bid items for services, traffic control devices, signing, etc. For projects with only light traffic where traffic control procedures are minimal, payment may be incidental to other items of work, or paid for on a lump-sum basis.

There may be certain traffic control information that is of value to the project engineer but should not be included in the contract. In this case, such information should be documented and copies provided to the appropriate construction units. This information may include the following:

- the need for public relations (e.g., notifications to the local news media);
- any special agreements reached with other agencies relating to traffic control or traffic management;
- crash reporting requirements; and
- any special guidance on traffic management for the project engineer.

The TTC plan as contained in the contract must be adopted by the contractor unless an alternate TTC plan is developed by the contractor and approved by the engineer prior to beginning construction operations.

- ☐ Estimated traffic volumes, vehicle types, and direction of travel.
- ☐ Traffic speeds.
- ☐ Required number of travel lanes.
- ☐ Traffic control layouts including signing, markings, channelization devices, traffic signals, traffic delineators, barriers, and detour schemes.
- ☐ Restrictions on work periods (e.g., rush hours, holidays, special events, nights, weekends).
- ☐ Characteristics of adjacent highway segments.
- ☐ Requirements for partial completion and opening sections to traffic.
- ☐ Maneuvering space available for traffic.
- ☐ Requirements for installing, maintaining, moving, or removing traffic control devices.
- ☐ Turns or cross movements required by traffic.
- ☐ Restrictions on contractor hauling or moving materials.
- ☐ Provisions for accommodating adjacent businesses or residential areas.
- ☐ Provisions for accommodating emergency vehicles (e.g., ambulance, fire, police).
- ☐ Any special requirements for the contractor's traffic safety coordinator.
- ☐ Requirements for after hours surveillance or on-call personnel.
- ☐ Special requirements for nighttime operations.
- ☐ Restrictions on parking vehicles, storing materials and the contractor's equipment.
- ☐ Special provisions for pedestrian and bicycle movements, including meeting the requirements of the *Americans with Disabilities Act*.
- ☐ Provisions for accommodating regularly scheduled services (e.g., postal vehicles, school buses).

Exhibit 8.4-F TRAFFIC CONTROL PLAN ITEMS

8.4.8.3 Temporary Pavement Markings

The TTC plan should reflect FLH policy that pavement markings conforming to full [MUTCD](#) standards shall be installed as quickly as practical in the construction process. Special standards described below are available to accommodate the periods of time before installation of permanent markings is practical.

8.4.8.3.1 Definitions

1. **Temporary Pavement Markings.** Either interim or standard markings installed prior to the installation of permanent markings.
2. **Interim Markings.** Interim markings are special, reduced dimension, temporary centerline and lane line markings, which are permitted by *MUTCD* Section 6F.72 or raised pavement markers permitted by Section 6F.73. Interim markings are permitted on new pavement lifts when additional pavement lifts or standard markings are to be installed within two weeks. Interim markings must conform to the color and retroreflective requirements of the *MUTCD*.
3. **Standard Markings.** Standard markings are centerline, lane line, and no-passing zone markings that comply fully with the dimensional, color and retroreflective requirements of the *MUTCD*. Standard markings may be either temporary or permanent, although permanent markings typically have additional contractual requirements.
4. **Vehicle Positioning Guides.** Temporary raised pavement markers, installed on centerline and lane lines immediately after paving but prior to the installation of temporary or permanent pavement markings.
5. **Severe Curvature.** Roads with a design speed of 55 km/h (35 mph) or less, or curves with design speeds of at least 15 km/h (10 mph) less than the design speed for the remainder of the road.

8.4.8.3.2 Unmarked Pavement

Section 6F.72 of the *MUTCD* permits a limited period of unmarked pavement upon opening to traffic and prior to the required installation of temporary or permanent markings. The traffic volume as outlined in [Sections 8.4.8.3.4](#) and [8.4.8.3.5](#) defines the time limitations. During this period, it is important that adequate delineation and signing be provided as follows:

- Vehicle positioning guides shall be installed on centerline and lane lines at a maximum spacing of N (N = cycle length, usually 12 m (40 ft)) in combination with appropriate signs, channelizing devices and other delineation. Spacing should be reduced to 0.5 N in severe curvature situations.
- A warning sign, "Unmarked Pavement," shall be placed at the beginning of each unmarked section, and after each major intersection or entrance ramp.

- If sections of severe curvature or restricted visibility dominate the construction area, such that passing zones are inappropriate throughout the project, standard advance warning signing at the beginning of the project shall include “No Passing Next [No.] Miles” rounded to the nearest whole meter (mile). In addition, an R 4-1 “Do Not Pass” sign shall be installed at the beginning of the project and approximately every 1.6 kilometers (1 mile) thereafter.
- If each no-passing zone is to be signed separately, an R 4-1 “Do Not Pass” sign shall be used at the beginning of each zone, and repeated at maximum 1.6 kilometer (1 mile) intervals, if necessary. At the end of each zone, an R 4-2 “Pass With Care” sign shall be used. On other than low-volume roads, and when special hazards are present, the R 4-1 sign at the beginning of each zone should be supplemented by a W 14-3 “No Passing Zone” sign.

8.4.8.3.3 Marked Pavement

Temporary markings are required if the time limitations as described below for Unmarked Pavement are exceeded and it remains impractical to install permanent markings. Temporary markings should be standard markings, unless the specific time limitations of temporary markings can be met. The following are special standards for temporary markings:

1. **Centerlines and Lane Lines.** [MUTCD](#) Section 6F.72 requires interim broken-line pavement markings to be 0.6-m (2-ft) stripes on 12-m (40-ft) cycles or 0.6-m (2-ft) stripes on 6-m (20-ft) cycles in severe curves. When 30 percent or more of the road is designated as meeting the criterion for severe curvature, the entire road may be striped on a 6-m (20-ft) cycle. Temporary raised pavement markers may be substituted for broken line segments with at least one on each end of each 0.6-m (2-ft) stripe and for solid lines at a spacing of one every 3 m (10 ft).
2. **Edge Lines.** Temporary edge lines are not required, except that if there is a winter shutdown or extended delay of six weeks or more in the completion of paving and installation of permanent markings. Temporary edge lines meeting the requirements of the *MUTCD* must be installed on those roads where edge lines were present prior to construction and permanent edge lines are specified in the contract.

8.4.8.3.4 Time Limitations — Low-Volume Roads (ADT < 1000)

Where average daily traffic does not exceed 1,000 vehicles per day, and where the installation of permanent markings is not practical or possible immediately prior to opening the road to traffic, the following applies:

- For a scheduled duration of not more than two weeks after opening of a new lift of pavement, the minimum requirements of [Section 8.4.8.3.2](#) apply.
- As an option to unmarked pavement during the same two-week time frame, temporary centerline markings meeting the standards of interim markings as defined in [Section 8.4.8.3.3](#) are permitted.

- For a scheduled duration of more than two weeks after the opening of a new lift of pavement, the minimum requirements of standard markings as defined in [Section 8.4.8.3.1](#) apply; as well as the requirements for edge lines in [Section 8.4.8.3.3](#).

8.4.8.3.5 Time Limitations — Other Than Low Volume Roads (ADT > 1000)

Where average daily traffic exceeds 1,000 vehicles per day, and where the installation of permanent pavement markings is not practical immediately prior to opening the road to traffic, the following applies:

- For a scheduled duration of not more than three days after the opening of a new lift of pavement, the minimum requirements of [Section 8.4.8.3.2](#) apply.
- For a scheduled duration of not more than two weeks after opening a new lift of pavement, the minimum requirements of interim markings as defined in [Section 8.4.8.3.3](#).
- For scheduled duration of more than two weeks after opening a new lift of pavement, the minimum requirements of standard markings as defined in [Section 8.4.8.3.1](#) as well as the requirements for edge lines in [Section 8.4.8.3.3](#) apply.

8.4.8.3.6 Contract Items

Contract requirements and contract items should be structured to assure safety while not subsidizing or encouraging delays, inefficiencies and excessive use of temporary markings and related traffic control.

Vehicle positioning guides are not considered centerline markings. They may be paid for as Vehicle Positioning Guides or considered a subsidiary obligation. Additional signing and/or channelization devices necessary during periods of unmarked pavement should be anticipated and included in the TTC plan.

Because the *Standard Specifications* (see [Section 9.4.11](#)) prohibit painted temporary markings on the final lift of pavement, it may be appropriate to include a contract item for temporary markings for lifts other than the final lift, but not for the final lift. This will minimize the cost of the temporary markings item and encourage the contractor to schedule permanent markings on the final lift in a timely manner.

8.4.8.3.7 No Existing Markings

Where the existing road, prior to construction, has no markings, then temporary markings are not required prior to completion of the work. However, if the construction is nearly complete, including one or more lifts of pavement materials, and has upgraded the geometrics and increased prevailing speeds, temporary markings are required in accordance with [Section 8.4.8.3.3](#).

8.4.8.3.8 One-Lane Paving

Where only one lane of a two-lane road is being paved during construction, and the second lane is paved the following day (permitted by the *FP* depending on lift thicknesses), the paving must be offset so that the existing markings are not obscured or temporary markings must be installed on the one lane mat prior to opening it to traffic. In addition, an UNEVEN LANES sign (W8-11) should be used in this situation.

8.4.8.3.9 Special Pavement Markings

The need for temporary school zone, railroad, cross walk, stop line and other special pavement markings must be evaluated on a case-by-case basis during the design process. Markings that are deemed warranted must be included in the contract. Bicycle and pedestrian traffic, limited sight distance and other potential hazards should be considered also during the design process as well as traffic volume and the duration of construction.

8.4.8.3.10 Diversions and Detours

Paved temporary roads and detours that carry other than low-volume traffic, or are to be used in excess of two weeks must receive the standard markings in accordance with the [MUTCD](#). When two-way traffic is detoured onto what would ordinarily be a one-way road, or what may appear to be a one-way road, signing must be supplemented with (W6-3) TWO-WAY TRAFFIC signs at maximum intervals of 1.6 km (1 mi).

8.4.8.3.11 State Standards

Designers should be cognizant of prevailing State standards and make adjustments (i.e., more stringent standards) to FLH requirements, wherever appropriate.

8.4.8.3.12 Contract Provisions

It is important to structure contracts so that major overruns and unnecessary government liability for short-term markings will not occur if the contractor elects to perform the paving and marking differently than the designer assumed. The following are general guidelines that must be reevaluated on a case-by-case basis:

- There should be sufficient quantities of temporary markings to accommodate each lift of paving materials anticipated during construction.
- The contractor should be given the option of furnishing painted markings, reflective tape or temporary raised pavement markers. The bid item should include removal when required. Generally, painted short-term markings are cheapest and are appropriate immediately behind the paving operation on intermediate lifts. The temporary raised pavement markers are more practical on final lifts since they are easily removable prior to installing permanent markings, and are usually less expensive than reflective tape on

roads with extensive no-passing zones. Where aesthetics are important, it may be appropriate to prohibit temporary painted markings on the final lift.

- The government is not obligated to pay for two systems on the same lift. If the time limit for short-term interim markings expires due to poor scheduling, and the contractor has to install short-term standard markings, then the upgrade should be at the contractor's expense.
- For large projects, it is intended that the time limitations on short-term interim markings will force the contractor to complete manageable sections of the project through permanent striping, rather than have the entire project partially complete for an unacceptably long period of time.

8.4.8.4 Channelizing Devices

The preferred channelizing device for any application involving both day and night usage is the drum. If clearance or width problems preclude the use of drums, other devices (e.g., vertical panels, barricades, tubular markers) may be substituted. All devices must meet current crashworthiness standards.

The TTC plan should address and contain appropriate standards defining the expected condition of the traveled way and the needs of the public through the duration of the project. Specific situations that should be addressed through the use of appropriate signing and channelizing devices in each TTC plan include the following:

1. **Delineating Isolated Hazards.** Delineating isolated hazards (e.g., partially complete guardrail, catch basins, major dropoffs).
2. **Protecting Workers.** Protecting works by separating traffic from an active short-term work site.
3. **Separating Opposing Lanes.** Separating opposing lanes of traffic in confined or detour situations.
4. **Tapers and Transitions.** Tapers and transitions that move traffic from one lane to another, on or off a detour, facilitate a merge, lane narrowing or a one-lane flagging situation.
5. **Delineating Continuous Hazards.** Delineating continuous hazards (e.g., shoulder dropoffs).
6. **Delineating the Traveled Way.** Delineating the traveled way through a work zone when no specific hazards are present. This use is often appropriate for low-volume roads where no detour or temporary pavement surface is provided, and traffic must be routed through the work zone. Once the permanent channelizing cues (e.g., delineators, pavement markings) are removed, temporary delineation must be provided, especially for nighttime traffic.

Depending on traffic volume, speed, duration of condition, geometrics and related risk assessment factors, Items one through six may warrant the use of a temporary concrete barrier. In high-risk situations channelizing devices should not be used alone where a positive barrier is warranted.

8.4.9 Traffic Signals

As most FLH Program work is in rural areas, there is seldom a need for signalized intersections or advanced traffic control systems (e.g., ramp monitoring on controlled access facilities). However, temporary signals are an effective tool for managing traffic where one-lane operations are required for bridge rehabilitation or similar work. Gather all available information on traffic volumes, turning movements and crash data (e.g., frequency, location, type, speeds).

The design of temporary traffic signal devices and warrants for their use are covered in the [*MUTCD*](#). Consult additional reference sources when designing signalized intersections and other traffic control systems not covered by the *MUTCD*. The *Traffic Control Devices Handbook* provides the fundamental procedures for proper analysis and design of traffic control systems as well as the *Highway Capacity Manual*.

Traffic control signals are devices that control vehicular and pedestrian traffic by assigning the right-of-way to various movements for certain pre-timed or traffic-actuated intervals of time. Traffic control signals are one of the key elements in the function of many urban streets and of some rural intersections. The planned signal system for a facility should be integrated with the design to achieve optimum safety, operation, capacity and efficiency. Careful consideration should be given in plan development to intersection and access locations, horizontal and vertical curvature, pedestrian requirements and geometric schematics to ensure the best possible signal progression, speeds and phasing. In addition to the initial installation, future needs should also be evaluated.

Owner agencies or State highway agencies are good sources for design assistance, particularly in the area of equipment compatibility and electrical design.

8.5 (RESERVED)

8.6 (RESERVED)

8.7 DIVISION PROCEDURES

Reserved for the Federal Lands Highway Division in supplementing the policy and guidelines set forth in this chapter with appropriate Division procedures and direction.

8.7.1 CFLD Procedures

To be provided.

8.7.2 EFLD Procedures

To be provided.

8.7.3 WFLD Procedures

To be provided.